Thermal & Magneto-Rotational Instability in the Interstellar Medium

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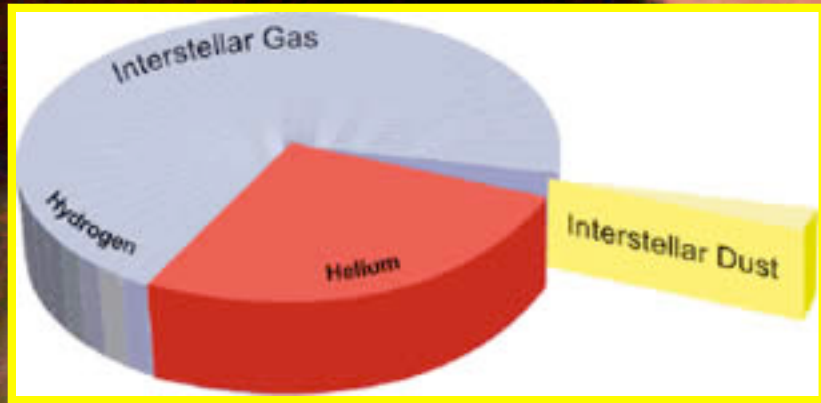# What is the ISM?

- **Chemical Composition**
  - 75% Hydrogen
  - 25% Helium
  - Dust, Molecules

- **Temperatures**
  - Giant molecular clouds (GMC) – as low as 10K
  - Hot medium – as high as 10^7 K, heat by SN shocks

- **Density**
  - Typically 1 particle cm^{-3} but up to 1000 cm^{-3} in GMCs

Thackeray's Globules in Nebula IC 2944   HUBBLESITE.org

Classical Theory of ISM

- **Cooling processes**
  - Emission -> atomic and molecular transitions
- **Heating processes**
  - UV light and photo-electric effect on dust grains
- **ISM exists in thermal equilibrium**
  - Short time scales -> may be a good assumption
- **ISM exists in pressure equilibrium**
  - Observationally constrained

Thermal Instability

- **Thermal equilibrium curve**

- **Net cooling above**

- **Net heating below**

- **Local shape of EQ curve determines stability**

- **Thermally unstable gas develops into a bi-stable medium**
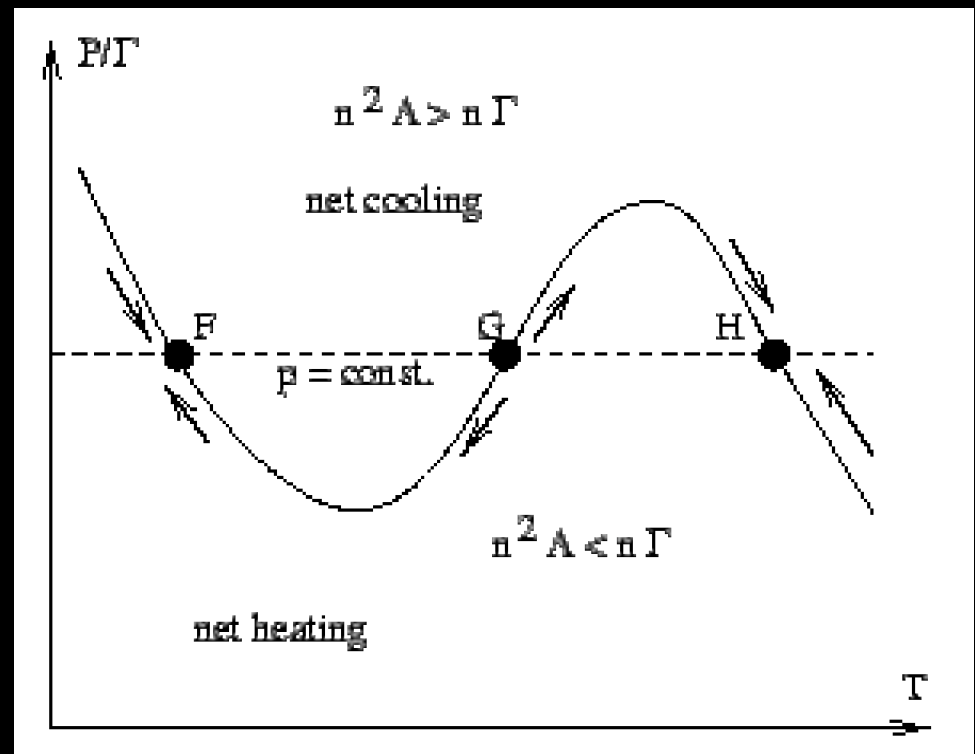
Magneto-Rotational Instability

- **Requirements to have MRI**
  - Differentially rotating (shearing) system
  - Angular velocity must decrease outward
  - Weak magnetic fields (not too strong)
- **Physical basis**
  - Fluid elements are displaced outward
  - Magnetic fields resist shear
  - Velocity at new location is now too large to maintain equilibrium
- **These are some of the first ISM simulations of MRI in a bi-stable medium**

ISM Simulations

- **ZEUS-2D**
  - **Time explicit, finite difference, staggered mesh**
  - **Artificial viscosity for shocks, CT for magnetic field**
- **Local 2D Simulations**
  - **100 pc Box, 512^2 Zones**
- **Shearing - periodic boundary conditions**
- **Subroutines for cooling and conduction**
- **Initial conditions**
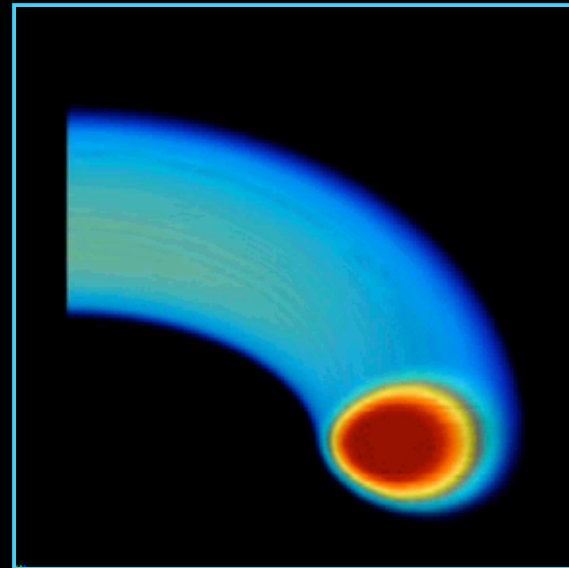
TI + MRI Simulations
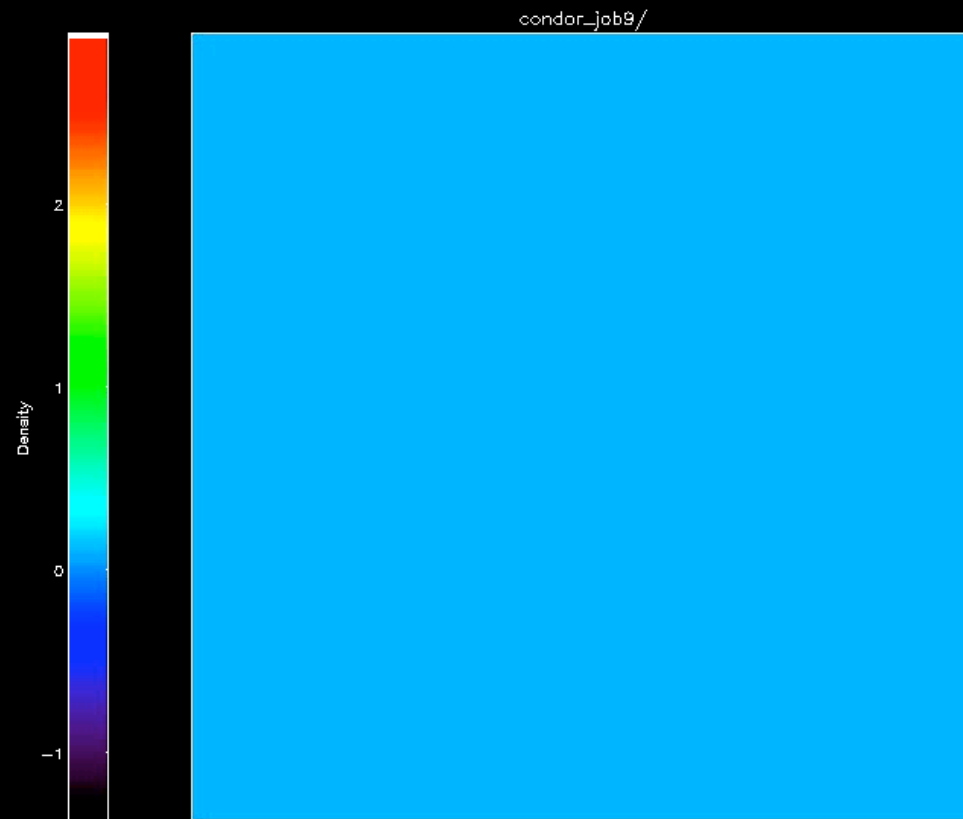
Future Simulations

- 3D simulations soon to follow as 2D channel solution gives way to fully developed turbulence
- Include additional physical effects
  - Supernova & stellar winds from massive stars
  - Self gravity - needed to form GMCs